# United States Patent

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[72] Inventor **Gerhard Heinrich Friedrich de Vries**
**Emmasingel, Eindhoven, Netherlands**
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[73] Assignee **U.S. Philips Corporation**
**New York, N.Y.**
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[33] **Netherlands**
[31] **6,708,463**

[54] **X-RAY TUBE WITH MAGNETIC FOCUSING MEANS**
**4 Claims, 4 Drawing Figs.**

[52] **U.S. Cl.** .......... **313/57,** 313/55, 250/90
[51] **Int. Cl.** .......... **H01j 35/14,** H01j 35/18
[50] **Field of Search** .......... 313/55, 57, 59; 250/87, 88, 89, 90, 99, 43.5 (4)

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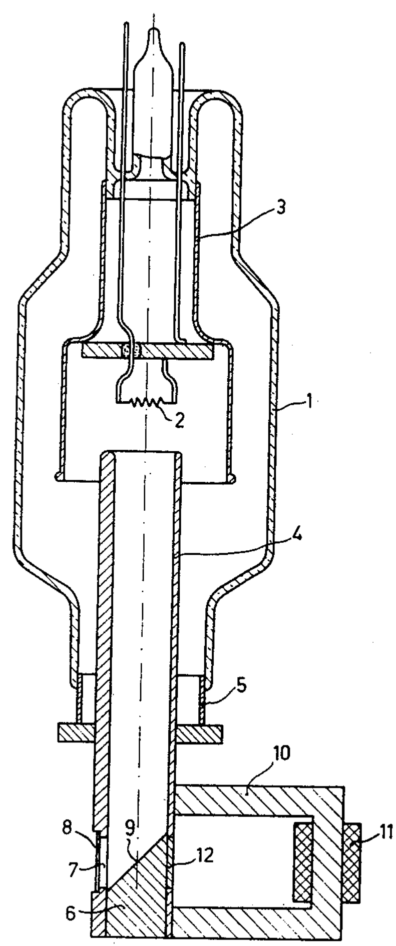
*Primary Examiner*—James W. Lawrence
*Assistant Examiner*—C. R. Campbell
*Attorney*—Frank R. Trifari

**ABSTRACT:** An X-ray tube having a beryllium window in a metal wall portion of the tube which is integral with the anode, the beam channel extending in the axial direction of the tube at the window being surrounded by a strong magnetic field the lines of force of which extend substantially parallel to the axis of the tube, the region of substantially constant field strength on the side of the tube cross section closed by the window having a maximum width.



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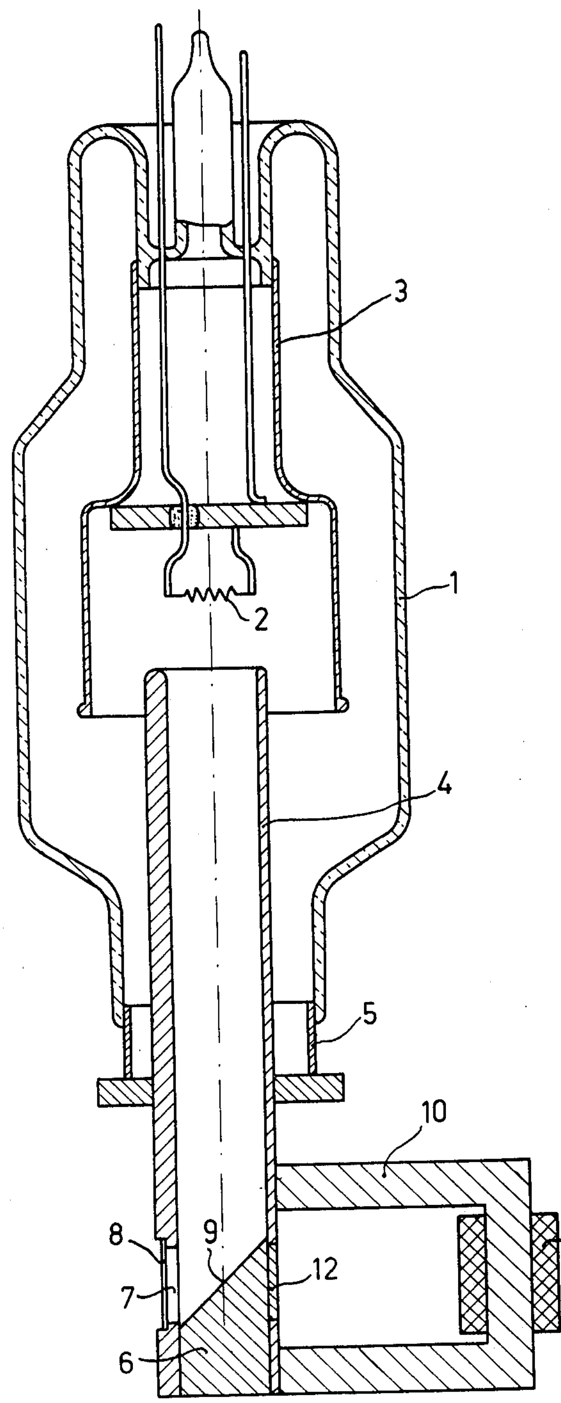


FIG.1

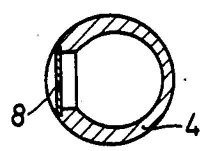


FIG.2

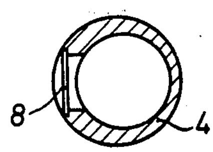


FIG.3

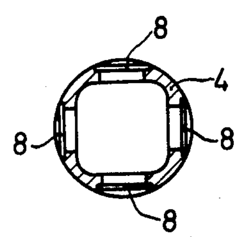


FIG.4


INVENTOR.
GERHARD H.F. DE VRIES
BY
AGENT

## X-RAY TUBE WITH MAGNETIC FOCUSING MEANS

This invention relates to an X-ray tube provided with an X-ray exit window which is made of beryllium and satisfactorily transmits soft X-rays having a wave length of not less than 15 A. The window is arranged in the metal wall of the tube. It is known to provide such a tube with means to prevent the window from being struck by electrons. For this purpose, the window is screened electrostatically, which is achieved when the window is at cathode potential or when a gauzelike electrode held at cathode potential is arranged between the window and the electron target on the anode of the X-ray tube. It is not always possible and with X-ray tubes having a metal wall often even undesirable to apply to the window and hence the wall of the tube insulated from the cathode the same potential as the cathode. Furthermore, it is undesirable to enlarge the distance from the electron target on the anode to the window, which is required to obtain a sufficient amount of space for accommodating a screening gauzelike electrode which is at cathode potential.

Electrons striking the anode with a high velocity and then terminating on the window due to elastic reflection are particularly harmful in an X-ray tube having a window transmitting soft rays, because for wavelengths exceeding 15 A. the thickness of the beryllium window is preferably not larger than 0.05 mm. so that this window has such a low heat capacity and such a low thermal conductivity that excessive heating owing to the energy of the rapid electrons is inevitable, as a result of which such a tube cannot be used for anode voltages exceeding those at which X-rays of the said wavelength are produced.

This invention has for its object to avoid this disadvantage. In an X-ray tube according to the invention, the beam channel extending in the axial direction of the tube is surrounded at the X-ray exit window and on its inner side by a strong magnetic field, the lines of force of which extend substantially parallel to the axis of the tube, while the region of substantially constant field strength at least on the side of the tube cross section closed by the window has a maximum width. In a known X-ray tube using a magnetic field, this field serves to promote the concentration of the electrons and the compression of the electron beams to a minimum cross section. The conventional electrostatic focusing, which is obtained by suitably shaping the support of the thermionic cathode, is sometimes insufficient and is especially unsatisfactory if the electrons are accelerated towards the anode over a comparatively large distance. In such cases, a magnetic focusing field is used which preferably has a small focal distance. For this purpose, it is known to provide pole pieces in the immediate proximity of the electron target in a manner such that a lateral passage for the X-rays is left free between the opposite poles.

Such a lens considerably contributes to the focusing with a maximum magnetic induction along the axis of the lens. The magnetic field strength required is obtained only under the influence of the saturation of the iron of the pole pieces.

Such a magnetic focusing field acts on the elastically reflected electrons released in the target on the anode as a stray field because the area at which the electrons are produced is located inside the operative range and in the proximity of the maximum strength of the lens field. The paths of these electrons, which have a high initial velocity, are not or substantially not influenced by the magnetic field in the proximity of the target. This accounts for the fact that with a sufficient strength of the field surrounding the electron paths, a minimum lens effect is advantageous to cause the electrons reflected from the anode to terminate under the influence of the said magnetic field on areas other than the tube window and even to conduct such electrons back to the anode.

An X-ray tube according to the invention will be described with reference to the drawing, in which:

FIG. 1 is a sectional view of the X-ray tube according to the invention; and

FIGS. 2, 3 and 4 are a few cross sections of the anode part of the tube at the level of the window.

A glass sheath **1** encloses a space which is exhausted to a vacuum and in which a thermionic cathode **2** is arranged, the support **3** of which is fused to the glass wall. A hollow metal tube **4** projecting beyond a seal **5** on the wall **1** terminates opposite the cathode **2**. The metal tube **4** consists of a ferromagnetic material, for example, iron and supports at its end a copper anode **6** by means of which the tube **4** is closed in a vacuum-tight manner. The conventional materials for cooling the anode are not shown in the drawing. The wall of the metal tube **4** is provided with an aperture or passage **7** for the X-rays, which aperture is closed by a thin-walled beryllium window **8** which has a thickness of, for example, about 0.05 mm.

Due to the mechanical and electrical connection between the window **8** and the anode tube **4**, the window is at the same potential as the anode **6**. When the cathode **2** and the anode **6** have applied to them the operating voltage, electrons elastically reflected from the anode surface **9** will be deflected towards the window **8** which is a target for such electrons, which are accelerated by the operating voltage applied and the velocity of which is hardly reduced by the deflection, is exposed to strong heating. The electrons are conducted away from the window by a magnetic field which along the beam channel constituted by the inner wall of the anode tube **4** at the level of the window annularly encloses the electron paths terminating on the anode. Such a strong magnetic field enclosing the electron paths is capable of varying sufficiently the direction of the penetrating electrons travelling towards the window so that such electrons pass the window, and strike other areas of the anode tube or return to the anode. The desired screening of the window is obtained by a magnetic field of not more than 5,000 Gauss.

Due to the low magnetic induction required to limit the field straying, a thick-walled anode tube **4** must be used which has an annular interruption at the level of the window **8**. When the poles formed due to the interruption are not excessively energized, the bore of the tube **4** is, so to say, magnetically screened so that the field in this space is suppressed. The field is produced by a magnetic yoke **10** which joins the anode tube **4** and is provided with an energizing magnet coil **11**. Alternatively, the required field may be produced by a permanent magnet. The interruption **12** provided in the anode tube **4** for forming the magnet poles is suitably bridged by a nonmagnetic material.

In order to ensure that the field is located as close as possible to the window **8**, it is efficacious to increase the wall thickness of the anode tube on this side. The cross sections of FIGS. **2** and **3** are shaped so that, while retaining a sufficiently strong field at the window, the anode tube may have a smaller weight. The shape of the cross section of FIG. **4** is preferred when two or more windows **8** transmitting X-rays in various directions are arranged, as is the case, for example, in multiple X-ray diffraction apparatus.

It has been found that the dimensions of the tube may be substantially equal to those of the construction without the window screening described.

We claim:

**1.** An X-ray tube comprising an evacuated envelope having a metal wall portion provided with a window therein for the transmission of X-rays having a wavelength of not less than 15 A., a cathode and an anode within said envelope defining a given axis within said envelope, said anode being integral with said wall portion having said window, and means in proximity to said anode for generating a magnetic field the lines of force of which extend substantially parallel to the axis of said tube, said window being positioned parallel to said axis whereby said window, in the absence of the magnetic field, is struck by scattered electrons from said anode, said magnetic field having a region of substantially constant field strength of maximum width in proximity to said window whereby scattered electrons from said anode are prevented from striking said window.

**2.** An X-ray tube as claimed in claim **1**, wherein the inner and the outer cross section of the metal wall are both circular and are eccentrically arranged with respect to each other, while the X-ray exit window is arranged in the thicker wall portion.

3. An X-ray tube as claimed in claim **1**, wherein the metal wall has an inner square cross section and an outer circular cross section.



4. An X-ray tube as claimed in claim **1** wherein the wall portion provided with the window is annular and has a larger thickness.